Arizona Agronomy Technical Note
Nutrient Management

Introduction

It is necessary to understand the different goals of nutrient management, and the methods used to achieve these goals. The methods used will depend on whether the producer's goals are short-term or long-term, and also on the relative mobility of the nutrients, the amounts taken up by the crops, tie-up and availability, and their potential for loss through leaching, runoff, and volatilization.

Common Terminology

Nitrogen (N) is generally considered to be a short-term input because the majority of the N is either taken up or lost during the year of application. There is certainly some carry-over; only about 50% of N from manure application is available during the year of application. Also, the soil organic matter releases 10-40 lb/ac N for each 1% of organic content. Finally, plant residues from the previous crops release N as they decompose. However, while very important for nutrient budgeting, these amounts of N are usually small relative to the total amount of N needed during the crop year. An exception is N fixation by a previous legume crop, where larger amounts of N (40-100 lb/ac or more) can be available to the subsequent crop.

Nutrients such as Phosphorus (P), Potassium (K), and many of the other essential nutrients can be applied with a different time frame for management, partly because of their relative immobility in the soil and partly because a smaller fraction of the amount applied is available during the year of application. For these reasons, the relative level of these nutrients in the soil can be more important than the specific quantity applied. Following are some common terms used to describe the application of these nutrients:

Soil Build-up – The nutrient level in the soil is not considered to be high enough for optimum plant uptake. The amount applied reflects the anticipated plant need and crop removal rate for the year **plus** an additional amount to build the level in the soil. Build-up may be fairly rapid (1-2 years) or somewhat slow (3-5 years or more).

Maintenance/Crop Uptake – The nutrient level in the soil **is** considered to be high enough for optimum plant uptake. The amount of nutrient applied reflects only the anticipated crop removal rate for the year. See Table 2 for average rates of nutrient removal by common crops in Arizona. **Crop Uptake** is also referred to as **Crop Removal** or **Agronomic Rate**.

Drawdown – The nutrient is not applied, or the amount applied is less than the anticipated crop removal rate. The nutrient level in the soil will probably decline. For example, this approach can be used if P levels are very high and the P Index indicates environmental concerns. It is also sometimes used for the essential micro-nutrients because the amounts required by the crop are much smaller and the soil drawdown is gradual.

Essential Nutrients

Essential nutrients, or elements, are those that are required by plants to complete their life cycle. Macronutrients are required in large amounts by plants, while micronutrients are required in much smaller amounts.

Carbon (C), hydrogen (H), and oxygen (O) are essential macronutrients that are obtained from the air as carbon dioxide and water. All of the other essential plant nutrients are taken up from the soil solution (except for N fixed in legumes), or in some cases can be absorbed directly by the leaves from the foliar application of nutrients in solution.

Table 1 lists the remaining 15 essential nutrients, their mobility in soil and in the plant, the ionic form for plant uptake, and some of the major functions performed during plant growth.

Table 1 – Essential Plant Nutrients

Category	Name	Symbol	Mobile in Plant?	Mobile in Soil? *	Plant-Available Form(s) in Soil Solution	Primary Functions in Plants
Primary Macronutrients	Nitrogen	N	Yes	Yes (NO_3^-) No (NH_4^+)	NH_4^+ NO_3^-	Chlorophyll synthesis Amino acid formation (proteins)
	Phosphorus	P	Yes	No	$H_2PO_4^-$ HPO_4^{2-}	Energy storage and transfer Cell division and enlargement
	Potassium	K	Yes	No	K^+	Regulation of stomata General plant metabolism
Secondary Macronutrients	Sulfur	S	No	Yes	SO_4^{2-}	Amino acid formation (proteins) – 2 amino acids contain sulfur Promotes nodulation of legumes for N fixation
	Calcium	Ca	No	No	Ca^{2+}	Root and leaf development Uptake of other nutrients
	Magnesium	Mg	Yes	No	Mg^{2+}	Central atom of chlorophyll molecule Activation of enzyme systems
Micronutrients	Boron	B	No	Yes	$H_2BO_3^-$ HBO_3^{2-}	Pollination Protein synthesis
	Chloride	Cl	Yes	Yes	Cl^-	Cation transport (K, Ca, Mg) Hydrolysis of water molecules
	Copper	Cu		No	Cu^{2+}	Protein synthesis Chlorophyll synthesis
	Iron	Fe	No	No	Chelates of Fe^{3+} and occasionally of $Fe2^+$	A catalyst for chlorophyll synthesis Respiratory enzyme systems
	Manganese	Mn	No	No	Mn^{2+}	Aids chlorophyll synthesis Increases the availability of P and Ca
	Molybdenum	Mo		Yes	MoO_4^{2-}	Vital for N fixation in legumes Synthesis of enzyme nitrate reductase in plants (NO_3^- to NH_4^+
	Nickel**	Ni		No	Ni^{2+}	Important in plant N metabolism
	Zinc	Zn	No	No	Zn^{2+}	Carbohydrate production Plant growth substances
	Cobalt***	Co			Co^{2+}	N fixation in legumes

* As indicated here, consider ion mobility in soil in terms of long-term nutrient management planning. As with soil clays, the ionic forms of nutrients that are not considered mobile will **slowly** move in the soil profile through leaching and transmigration.
** Nickel is essential for plants that are supplied with urea and for plants in which ureides play a significant role in nitrogen metabolism.
***Essential nutrient for legumes

Interpreting Soil Test and Plant Analysis Results

In order to write a nutrient management plan or to document the implementation of a nutrient management plan, it is critical to keep the units straight between soil test results, plant analysis results, and fertilizer applications.

For example, all fertilizer formulations have nitrogen (N) listed in its elemental form. If a fertilizer is 10-34-0, it is 10% N. Another way to look at it is that every 100 pounds of 10-34-0 is guaranteed to have 10 pounds of N.

However, all fertilizer formulations actually list phosphorus (P) as P_2O_5, which is the oxide form (commonly called phosph**ate** in fertilizer formulations). Potassium (K) is also shown in its oxide form as the amount of K_2O, often called pot**ash**. The numbers used for fertilizer formulations represent **%N-%P_2O_5-%K_2O** (see Table 3).

Soil Test Units

By using chemical extractants to calculate the soluble fraction of each nutrient, soil test results **estimate nutrient availability present at the time the soil sample was taken**. Results are typically reported in parts per million (ppm) in **elemental** form for the nutrients analyzed. First of all. this requires that ppm be converted to pounds per acre. Fortunately, this conversion is quite simple. The weight of one acre of soil, 6.67 inches deep, is approximately 2 million pounds. To make the arithmetic easier, 6.67 inches is often rounded down to 6 inches. Many soil tests are also taken to the depth of 6 inches (this depth is sometimes referred to as an “acre furrow slice”). In this case,

(Soil sample depth/6) x ppm x 2 = pounds per acre

Example: a soil test result indicates 16 ppm of phosphorus (P). The sample was taken to a depth of 6 inches.

(6 inch sample depth/6) x 16 ppm x 2 = 32 pounds P per acre

The older Nutrient Budget worksheet used in Arizona assumed a soil sample depth of 6.67 inches, and automatically made this calculation. The new Nutrient Budget specification requires the user to enter the depth of soil sampled, and then calculates pounds per acre based on the actual depth sampled. **When you are using this specification, make sure you know the sample depth if it is not listed on the soil test results.**

Next, P and K need to be converted to P_2O_5 and K_2O, respectively. There are simple formulas to convert the amount of elemental P and K to their equivalent amounts in the oxide form. They are based on the respective atomic and molecular weights of each element and oxide:

Conversion Factors between Phosphorus (elemental form) and Phosphate Fertilizer (oxide form)

P x 2.29 = P_2O_5

P_2O_5 x .44 = P

Example: A fertilizer recommendation is for 50 lb. of P. How many pounds of P_2O_5 will be required?

50 lb. P x 2.29 = 115 lb. P_2O_5

Conversion Factors between Potassium (elemental form) and Potash Fertilizer (oxide form)

K x 1.21 = K_2O

K_2O x .83 = K

Example: A fertilizer recommendation is for 50 lb. of K. How many pounds of K_2O will be required?

50 lb. K x 1.21 = 61 lb. K_2O

Plant Analysis Units

The term “plant analysis” refers to the total or quantitative analysis of nutrients in plant tissue, and is done in a laboratory. This should not be confused with field tissue testing, which is a qualitative, on-the spot measure of plant nutrient content. Field tissue testing is also known as petiole tissue testing.

The results of plant analysis are commonly used to identify in-season plant nutrition problems in time to address them for the current crop. They are also used as a diagnostic tool for the longer-term correction of nutrient deficiencies in subsequent crop years.

Plant analysis results indicate **nutrient uptake by the plant**. Results typically list the macronutrients as percentages, while the micronutrients are shown as ppm. These are then compared to sufficiency ranges that have been established by research. Most often, results for nutrients are shown as:

VL – very low
L – low
M – medium or moderate
H – High
VH – very high

For the categories of VL and L, the nutrient level is below the sufficiency range for that nutrient and a positive crop response is likely. For M, the value is within the sufficiency range; a crop response is possible, however (this will depend on crop, growth stage, and numerous other factors). For the categories of H and VH, an in-season crop response is unlikely.

Calculating Nutrient Inputs from Fertilizer Applications

Fertilizer formulations list nutrient content as **%N-%P_2O_5-%K_2O**. Sometimes other nutrients such as S and Zn are also listed if they are present. Since nowadays many fertilizer sources are in liquid form and are applied by banding in the soil or by fertigation in irrigation water, they are often applied in gallons per acre. In addition to the formulation it is necessary to know the weight of a gallon of that formulation. Table 3 lists many of the formulations commonly used in Arizona, their form, and their weight if applied as a liquid.

Table 3 - Common Fertilizer Formulations

Source	Typical Analysis %N-%P_2O_5-%K_2O	Physical Form	Pounds per Gallon @ 60^{0}F
Anhydrous ammonia, NH_3	82-0-0	Liquid under pressure, gas at reduced pressure	5.14
Urea, $(NH_2)_2CO$	46-0-0	solid	
UAN, U28, U32 (urea plus ammonium nitrate solution)	28-0-0 to 32-0-0	liquid	10.66 to 11.06
Ammonium nitrate, NH_4NO_3	33.5-0-0 or 34-0-0	solid	
Ammonium sulfate, $(NH_4)_2SO_4$	21-0-0	solid	
Calcium nitrate, $Ca(NO_3)_2.2H_2O$	15.5-0-0	solid	
Calcium ammonium nitrate (CAN), NH_4NO_3 plus lime	27-0-0	solid	
Aqua ammonia, NH_4OH	20-0-0	liquid	7.6
Ammonium polyphosphate	10-34-0 to 11-37-0	liquid	11.4 to 11.7
Normal superphosphate, $Ca(H_2PO_4)_2$	0-18-0 to 0-20-0	solid	
Triple superphosphate, $Ca(H_2PO_4)_2$	0-44-0 to 0-46-0	solid	
Monoammonium phosphate (MAP), $NH_4H_2PO_4$	10-50-0 to 11-52-0	solid	
Diammonium phosphate (DAP), $(NH_4)_2H_2PO_4$	18-46-0	solid	
Potassium chloride, KCl	0-0-60 to 0-0-62	solid	
Potassium sulfate, K_2SO_4	0-0-50	solid	
Potassium nitrate, KNO_3	13-0-44	solid	
Langbeinite (Sul-Po-Mag, K-Mag)	0-0-22	solid	

Table 2 – Pounds of Nutrients Removed by Common Arizona Crops (Harvested Portion-Crop Removal Rates)

	Corn (grain), per 1000 lbs. of grain	Winter Wheat, per 1000 lbs. of grain	Barley, per 1000 lbs. of grain	Cotton (lint and seed) per bale (500 lbs) of lint	Pinto Beans, per 1000 lbs of beans	Pecans (nuts only), per 1000 lb. of nuts	Alfalfa (early bloom), per ton of hay	Sorghum/ Sudan, per ton of hay	Corn for silage, per ton of silage	Carrots, per 1000 lbs. of carrots	Lettuce (head), per 1000 lbs. of lettuce
Nitrogen (N)	14.2	23.0 (Durum wheat)	18.6 (6-row)	45.6	37.4	23.8	54.6	32.8	7.1	1.8	2.0
Nitrogen (N)-Typical production application rates [6]	27.5	38 (Durum wheat)	30.5 (6-row)	83	NA	80	0-except during planting.	67 (per ton of grain)	8.3[7]	NA	7.1
Phosphorus (P)	2.7	3.8	3.7	5.7	4.8	3.2	4.1	5.4	1.1	0.4	.25
Potassium (K)	3.0	4.3	4.7	6.8	13.3	5.0	42.0	39.6	6.0	2.9	2.4
Calcium (Ca)	4.4	4.4	0.29	7	2.2	0.7	32				
Magnesium (Mg)	5.8	5.0		11.5		1.2	6.75				
Sulfur (S)	8.0	14.2		1			4				
Zinc (Zn)	0.018	0.024		0.03		0.045	0.05				
Iron (Fe)	0.012	0.687		0.035	0.059	0.03	0.375				
Boron (B)	.007			0.025			0.05				
Manganese (Mn)	0.010	0.050		0.15		0.045	0.25				
Copper (Cu)	0.006	0.013		0.015		0.012	0.015				
Nickel (Ni)											
Chloride (Cl)							0.25				
Molybdenum (Mo)	0.004			0.01			0.002				
Cobalt (Co)											

Notes

1. The numbers shown are averages only. Moisture content, protein content (especially for N), and other factors will result in somewhat different numbers.
2. P and K are shown in the elemental form. To convert to pounds in the oxide (plant available) form, use the conversion factors on page 3.
3. The numbers shown can be used to calculate **nutrient removal rates** from the field, and also to highlight the removal of secondary macro-nutrients and micro-nutrients (where good information is available). Remember that both University and Industry recommendations, especially for N, factor in less than 100% efficiency of use. Recommendations for N also may factor in the nutrients needed to grow the plant each year, especially if they are general recommendations and are not based on site-specific information such as recent soil test or plant analysis information.
4. Cotton nutrient information is based on Soil Fertility Manual from the International Plant Nutrition Institute. All other Primary macronutrient information comes from the USDA Plants Database Crop Nutrient Tool.
5. Information for crops not listed here may be found by using the Crop Nutrient Tool on the USDA- Plants website.
6. From U of A Nitrogen Fertilizer Management in Arizona, page 7 and/or individual crop management guides within this document, and based on high yield values.
7. From "Agri-Facts" http://www.back-to-basics.net/agrifacts/pdf/b2b22.pdf.

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